



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) **EP 1 336 657 A1**

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 158(3) EPC

(43) Date of publication:
20.08.2003 Bulletin 2003/34

(51) Int Cl.7: **C12N 15/54, C12N 1/21,
C12P 7/66, C12N 9/12**

(21) Application number: **01982863.1**

(86) International application number:
PCT/JP01/10119

(22) Date of filing: **20.11.2001**

(87) International publication number:
WO 02/040682 (23.05.2002 Gazette 2002/21)

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR**

(30) Priority: **20.11.2000 JP 2000352940**

(71) Applicant: **KANEKA CORPORATION**
Osaka-shi, Osaka 530-8288 (JP)

(72) Inventors:
• **MATSUDA, Hideyuki**
Matsue-shi, Shimane 690-0815 (JP)

• **KAWAMUKAI, Makoto**
Matsue-shi, Shimane 690-0823 (JP)
• **YAJIMA, Kazuyoshi**
Akashi-shi, Hyogo 673-0005 (JP)
• **IKENAKA, Yasuhiro**
Kobe-shi, Hyogo 651-2242 (JP)

(74) Representative: **HOFFMANN EITLE**
Patent- und Rechtsanwälte
Arabellastrasse 4
81925 München (DE)

(54) **PROCESS FOR PRODUCING COENZYME Q 10?**

(57) The invention aims at providing a process for producing coenzyme Q₁₀ efficiently in microorganisms by utilizing a coenzyme Q₁₀ side chain synthesis gene derived from a fungal species belonging to the genus *Rhodotorula*.

The present invention relates to a DNA having a

DNA sequence described under SEQ ID NO:1, 3 or 5 or derived from the above sequence by deletion, addition, insertion and/or substitution of one or several bases and encoding a protein having decaprenyl diphosphate synthase activity.

EP 1 336 657 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a process for producing coenzyme Q₁₀, which is in use as a drug or the like. More particularly, it relates to a process for causing formation of coenzyme Q₁₀ by isolating a gene coding for a coenzyme Q₁₀ side chain synthase, which serves as a key enzyme in the biosynthesis of coenzyme Q₁₀, namely a decaprenyl diphosphate synthase, from a fungal species belonging to the genus *Rhodotorula* and introducing that gene into a host microorganism.

BACKGROUND ART

[0002] An industrial process for producing coenzyme Q₁₀ which is conventional in the art, comprises, for example, isolating coenzymes Q of plant origin, for example of tobacco origin, and adjusting the side chain length thereof by a synthetic method.

[0003] It is known that coenzyme Q₁₀ is produced in a wide variety of organisms, from microorganisms, such as bacteria and yeasts, to higher animals and plants. Thus, the process comprising cultivating a microorganism and extracting this substance from cells thereof can be regarded as one of the most efficient process for producing Q₁₀ and has actually been employed in commercial production thereof. However, the productivity of such processes can hardly be said to be good, since the yield is low and the procedure is complicated, for instance.

[0004] As for analogs (e.g. coenzyme Q₈) differing in chain length from coenzyme Q₁₀, not Q₁₀ itself, attempts have also been made to increase the production thereof by isolating genes involved in the biosynthesis thereof and amplifying the genes utilizing the recombinant DNA technology.

[0005] Coenzyme Q₁₀ is formed *in vivo* in a multistage process comprising complicated reactions in which a number of enzymes are involved. The route of biosynthesis thereof in prokaryotes partially differs from that in eukaryotes. Basically, however, each route comprises three fundamental steps, namely the step of synthesis of decaprenyl diphosphate, which is the source of the prenyl side chain of coenzyme Q₁₀, the step of synthesis of para-hydroxybenzoic acid, which is the source of the quinone ring, and the step of completion of coenzyme Q₁₀ through coupling of these two compounds and successive substituent conversions. Among these reactions, the reaction which determines the side chain length of coenzyme Q₁₀, namely the decaprenyl diphosphate synthase-involving reaction, which is said to be a rate-determining one in the whole biosynthetic reaction route, is considered to be the most important one.

[0006] Therefore, for efficient production of coenzyme Q₁₀, it is considered effective to isolate a decaprenyl diphosphate synthase gene, which is the key gene in the biosynthesis of coenzyme Q₁₀, and utilize the same for the purpose of increasing production. As for the gene source, fungi, in which coenzyme Q₁₀ is produced in relatively large amounts, are leading candidates.

[0007] So far, decaprenyl diphosphate synthase genes have been isolated from several microorganisms, such as *Schizosaccharomyces pombe* (JP-A-09-173076) and *Gluconobacter suboxydans* (JP-A-10-57072). However, the productivity of coenzyme Q₁₀ in these microorganisms cannot be said to be satisfactory, and the cultivation of these microorganisms and the separation/purification of coenzyme Q₁₀ therefrom have not been efficient. It has thus been desired that a microorganism-derived gene for that enzyme, which enables high level production of coenzyme Q₁₀, be isolated.

SUMMARY OF THE INVENTION

[0008] It is an object of the present invention to produce coenzyme Q₁₀ efficiently in microorganisms by isolating a coenzyme Q₁₀ side chain synthesis gene from a fungal species belonging to the genus *Rhodotorula* and utilizing the same to thereby solve the above-mentioned productivity problem.

[0009] For attaining the above object, the present inventors made investigations in an attempt to isolate a decaprenyl diphosphate synthase gene from fungi belonging to the genus *Rhodotorula*, in which coenzyme Q₁₀ is produced in relatively large amounts, and succeeded in isolating such gene. As a result of further investigations made by them to increase the expression level of that gene, they succeeded in improving the gene so that coenzyme Q₁₀ may be expressed more abundantly. These successes have now led to completion of the present invention.

[0010] Thus, the present invention provides
a DNA of the following (a), (b) or (c):

- (a) a DNA whose base sequence is as described under SEQ ID NO:1;
- (b) a DNA having a DNA sequence derived from the base sequence shown under SEQ ID NO:1 by deletion, addition, insertion and/or substitution of one or several bases and

encoding a protein having decaprenyl diphosphate synthase activity;
 (c) a DNA capable of hybridizing with a DNA comprising the base sequence shown under SEQ ID NO:1 under stringent conditions and
 encoding a protein having decaprenyl diphosphate synthase activity.

[0011] The invention further provides a DNA improved in its expression in prokaryotes, namely a DNA of the following (d), (e) or (f):

(d) a DNA whose base sequence is as described under SEQ ID NO:3;
 (e) a DNA having a DNA sequence derived from the base sequence shown under SEQ ID NO:3 by deletion, addition, insertion and/or substitution of one or several bases and
 encoding a protein having decaprenyl diphosphate synthase activity;
 (f) a DNA capable of hybridizing with a DNA comprising the base sequence shown under SEQ ID NO:3 under stringent conditions and
 encoding a protein having decaprenyl diphosphate synthase activity.

[0012] The invention further provides a DNA improved in its expression in prokaryotes, namely a DNA of the following (k), (l) or (m):

(k) a DNA whose base sequence is as described under SEQ ID NO:5;
 (l) a DNA having a DNA sequence derived from the base sequence shown under SEQ ID NO:5 by deletion, addition, insertion and/or substitution of one or several bases and
 encoding a protein having decaprenyl diphosphate synthase activity;
 (m) a DNA capable of hybridizing with a DNA comprising the base sequence shown under SEQ ID NO:5 under stringent conditions and
 encoding a protein having decaprenyl diphosphate synthase activity.

[0013] The invention further provides a protein of the following (g) or (h):

(g) a protein whose amino acid sequence is as described under SEQ ID NO:2;
 (h) a protein having an amino acid sequence derived from the amino acid sequence shown under SEQ ID NO:2 by deletion, addition, insertion and/or substitution of one or several amino acid residues and having decaprenyl diphosphate synthase activity.

[0014] The invention further provides a protein of the following (i) or (j):

(i) a protein whose amino acid sequence is as described under SEQ ID NO:4;
 (j) a protein having an amino acid sequence derived from the amino acid sequence shown under SEQ ID NO:4 by deletion, addition, insertion and/or substitution of one or several amino acid residues and having decaprenyl diphosphate synthase activity.

[0015] The invention further provides a protein of the following (n) or (o):

(n) a protein whose amino acid sequence is as described under SEQ ID NO:6;
 (o) a protein having an amino acid sequence derived from the amino acid sequence shown under SEQ ID NO:6 by deletion, addition, insertion and/or substitution of one or several amino acid residues and having decaprenyl diphosphate synthase activity.

[0016] The invention further provides DNAs respectively encoding the above proteins (g) to (j).

[0017] The invention further provides expression vectors with the above DNAs inserted into vectors.

[0018] The invention further provides transformants resulting from transformation of host microorganisms with the respective DNAs mentioned above or with the expression vectors mentioned above.

[0019] The invention further provides
a DNA encoding the protein (n) or (o).

[0020] The invention further provides
expression vectors with the above DNA inserted into vectors.

[0021] The invention further provides
transformants resulting from transformation of host microorganisms with the respective DNAs mentioned above
or with the expression vectors mentioned above.

[0022] The invention still further provides
a process for producing coenzyme Q₁₀.

which comprises cultivating any of the above-mentioned transformants in a medium and recovering coenzyme
Q₁₀ thus formed and accumulated in the medium.

DETAILED DISCLOSURE OF THE INVENTION

[0023] In the following, the present invention is described in detail.

[0024] The present inventors made investigations to isolate a gene encoding the enzyme in question from fungi
belonging to the genus *Rhodotorula*, in which coenzyme Q₁₀ is produced in relatively large amounts, and, as a result,
succeeded in obtaining a fragment of the gene by the PCR method.

[0025] The sequence of a known gene encoding a decaprenyl diphosphate synthase was compared with that of a
known gene encoding a polyprenyl diphosphate synthase which is an analogue with different chain length of the enzyme
in question and a long prenyl chain synthase of coenzyme Q, to the decaprenyl diphosphate synthase, and various
PCR primers were synthesized for regions showing high homology therebetween. PCR conditions were studied for
various combinations of these primers and, as a result, it was revealed, by gene base sequence analysis, that when
40 PCR cycles, each comprising 94°C, 1 minute → 43°C, 2 minutes → 72°C, 2-minutes, are carried out after 3 minutes
of heat treatment at 94°C, using the primers DPS-1 (5'-AAGGATCCTNYTNCAYGAYGT-3') and DPS-1 1AS
(5'-ARYTGNADRAAYTCNCC-3') (in these sequences, R representing A or G, Y representing C or T, and N representing
G, A, T or C), a fragment, about 220 bp in size, of the enzyme gene in question is amplified from the chromosomal
gene of *Rhodotorula minuta* IFO 0387, which is a fungal species belonging to the genus *Rhodotorula*.

[0026] For obtaining the enzyme gene in its full length, the chromosomal gene of *Rhodotorula minuta* IFO 0387 was
cleaved with the restriction enzyme EcoRI, and the cleavage products were inserted into a λ phage vector to construct
a recombinant phage library. The resulting plaques were transferred to a nylon membrane, and plaque hybridization
was carried out using the PCR fragment in a labeled form, whereby a clone having the decaprenyl diphosphate synthase
gene in its full length could be obtained.

[0027] The base sequence of the decaprenyl diphosphate synthase gene contained in the clone obtained was de-
termined, whereupon it was revealed that it has the sequence shown under SEQ ID NO:1 in the sequence listing. In
the amino acid sequence (amino acid sequence described under SEQ ID NO:2 in the sequence listing) predicted from
this base sequence, there was found a sequence characteristic of decaprenyl diphosphate synthase.

[0028] Since, in eukaryotes, the decaprenyl diphosphate synthase gene is expressed and functions in the mitochon-
dria, it is supposed that, in the sequence on the amino acid terminal side of this gene sequence, there be a sequence
allowing localization thereof in the mitochondria. Therefore, the inventors considered that, for more effective functioning
of this gene in prokaryotes, it be necessary to specify and eliminate that or those sequences which is or are not essential
in prokaryotes. As a result of studies on the amino acid terminal side sequence of that gene sequence, it has become
possible to produce coenzyme Q₁₀ in significant amounts by using the gene specified under SEQ ID NO:3. The amino
acid sequence deducible from the DNA sequence shown under SEQ ID NO:3 is described under SEQ ID NO:4 in the
sequence listing. As a result of further studies on the amino acid terminal side sequence, it has become possible to
produce coenzyme Q₁₀ in significant amounts by using the gene specified under SEQ ID NO:5. The amino acid se-
quence deducible from the DNA sequence shown under SEQ ID NO:5 is described under SEQ ID NO:6 in the sequence
listing.

[0029] The DNA of the present invention may be a DNA whose base sequence is as described under SEQ ID NO:
1 or SEQ ID NO:3, or a DNA having a base sequence derived from the base sequence shown under SEQ ID NO:1 or
SEQ ID NO:3 by deletion, addition, insertion and/or substitution of one or several bases and encoding a protein having
decaprenyl diphosphate synthase activity, or a DNA capable of hybridizing with a DNA comprising the base sequence
shown under SEQ ID NO:1 or SEQ ID NO:3 under stringent conditions and encoding a protein having decaprenyl
diphosphate synthase activity. A number of amino acids each may be encoded by one or more codons (genetic code
degeneracy), so that a number of DNAs other than the DNA having the base sequence shown under SEQ ID NO:1 or
SEQ ID NO:3 can encode the protein having the amino acid sequence shown under SEQ ID NO:2 or SEQ ID NO:4.
Therefore, the DNA of the invention includes such DNAs encoding the protein having the amino acid sequence shown
under SEQ ID NO:2 or SEQ ID NO:4 as well.

[0030] The DNA of the present invention may be a DNA whose base sequence is as described under SEQ ID NO: 5, or a DNA having a base sequence derived from the base sequence shown under SEQ ID NO:5 by deletion, addition, insertion and/or substitution of one or several bases and encoding a protein having decaprenyl diphosphate synthase activity, or a DNA capable of hybridizing with a DNA comprising the base sequence shown under SEQ ID NO:5 under stringent conditions and encoding a protein having decaprenyl diphosphate synthase activity. A number of amino acids each may be encoded by one or more codons (genetic code degeneracy), so that a number of DNAs other than the DNA having the base sequence shown under SEQ ID NO:5 can encode the protein having the amino acid sequence shown under SEQ ID NO:6. Therefore, the DNA of the invention includes such DNAs encoding the protein having the amino acid sequence shown under SEQ ID NO:6 as well.

[0031] The expression "base sequence derived by deletion, addition, insertion and/or substitution of one or several bases" as used herein means a base sequence resulting from deletion, addition, insertion and/or substitution of such a number of bases as can be deleted, added, inserted and/or substituted according to the methods well known to those skilled in the art, for example those described in Supplemental issue, Tanpakushitsu, Kakusan, Koso (Protein, Nucleic Acid and Enzyme), PCR Method for Gene Amplification, TAKKAJ, 35 (17), 2951-3178 (1990) or Henry A. Erlich (ed.), translated into Japanese under the supervision of Ikunoshin Kato: PCR Technology (1990).

[0032] The expression "DNA capable of hybridizing with a DNA comprising the base sequence shown under SEQ ID NO:1 (or SEQ ID NO:3 or SEQ ID NO:5) under stringent conditions" means a DNA obtainable by utilizing the technique of colony hybridization, plaque hybridization or southern hybridization, among others, using a DNA comprising the base sequence shown under SEQ ID NO:1 (or SEQ ID NO:3 or SEQ ID NO:5) as a probe. Those skilled in the art would be able to readily obtain the desired DNA by carrying out such hybridization according to the method described in Molecular Cloning, 2nd edition (Cold Spring Harbor Laboratory Press, 1989).

[0033] The expression "protein having decaprenyl diphosphate synthase activity" means a protein capable of synthesizing decaprenyl diphosphate in a yield of not less than 10%, preferably not less than 40%, more preferably not less than 60%, still more preferably not less than 80%, as compared with the case where a protein having the amino acid sequence shown under SEQ ID NO:2, SEQ ID NO:4 or SEQ ID NO:6. Such capacity can be measured by reacting FPP (farnesyl diphosphate) with ^{14}C -IPP (radiolabeled isopentenyl diphosphate) in the presence of the enzyme in question, hydrolyzing the resulting ^{14}C -DPP (decaprenyl diphosphate) with phosphatase and, after separation by TLC, determining the incorporation in each spot for each chain length (Okada et al., Eur. J. Biochem., 255, 52-59).

[0034] The protein of the invention may be a protein whose amino acid sequence is as described under SEQ ID NO: 2, SEQ ID NO:4 or SEQ ID NO:6, or a protein having an amino acid sequence derived from the amino acid sequence shown under SEQ ID NO:2, SEQ ID NO:4 or SEQ ID NO:6 by deletion, addition, insertion and/or substitution of one or several amino acid residues and having decaprenyl diphosphate synthase activity.

[0035] "Such an amino acid sequence derived by deletion, addition, insertion and/or substitution of one or several amino acid residues" can be obtained by deleting, adding, inserting and/or substituting an amino acid residue or residues by site-specific mutagenesis or any other methods well known in the art. Such methods are specifically described, for example, in Nucleic Acid Res., 10, 6487 (1982) and Methods in Enzymology, 100, 448 (1983).

[0036] For causing expression of the decaprenyl diphosphate synthase gene, it is necessary to connect that gene to a site downstream of an appropriate promoter. It is possible to construct an expression vector, for example, by excising a DNA fragment containing the gene using a restriction enzyme or amplifying an enzyme-encoding gene portion alone by PCR and then inserting the fragment or amplification product into a promoter-containing vector.

[0037] In the practice of the invention, the vector in which a DNA encoding a protein having decaprenyl diphosphate synthase activity is to be inserted to give an expression vector is not particularly restricted but may be one derived from an *Escherichia coli*-derived plasmid with an appropriate promoter inserted therein. The *Escherichia coli*-derived plasmid includes, among others, pBR322, pBR325, pUC19, and pUC119, and the promoter includes, among others, the T7 promoter, trp promoter, tac promoter, lac promoter, and λ PL promoter. In the practice of the invention, pGEX-2T, pGEX-3T, pGEX-3X (the three being products of Pharmacia), pBluescriptII, pUC19, pUC18 (product of Toyobo Co., Ltd.), pMALC2, pET-3T, pUCNT (described in WO 94/03613) and the like may also be used as vectors for expression. Among these, pUCNT is judiciously used. In specific examples, a decaprenyl diphosphate synthase gene expression vector, pNTRm2, can be constructed by inserting a DNA comprising the base sequence shown under SEQ ID NO:1 into the vector for expression pUCNT, and an expression vector, pNTRm6, can be constructed by inserting a DNA comprising the base sequence shown under SEQ ID NO:3 into pUCNT. An expression vector, pUCRm3, can be constructed when a DNA comprising the base sequence shown under SEQ ID NO:5 is inserted into the vector for expression pUC18.

[0038] And, by introducing the above enzyme gene expression vector into an appropriate microorganism, it becomes possible to utilize the microorganism for the production of coenzyme Q_{10} . The host microorganism is not particularly restricted but *Escherichia coli* is judiciously used. The *Escherichia coli* strain is not particularly restricted but includes XL1-Blue, BL-21, JM109, NM522, DH5 α , HB101, DH5, and pUC18, among others. Among these, *Escherichia coli* HB101 and pUC18 are judiciously used. For example, when the decaprenyl diphosphate synthase gene expression

vector pNTRm2, pNTRm6 or pUCRm3 is introduced into *Escherichia coli*, this can be transformed so that coenzyme Q₁₀, which *Escherichia coli* originally does not produce, can be produced in significant amounts. The *Escherichia coli* strain with pNTRm2 introduced therein has been deposited, under the Budapest Treaty, with the National Institute of Advanced Industrial Science and Technology International Patent Organism Depository (Central 6, 1-1-1 Higashi, Tsukuba, Ibaraki, Japan) under the designation *E. coli* HB101(pNTRm2) FERM BP-7333, the *Escherichia coli* strain with pNTRm6 introduced therein under *E. coli* HB101<pNTRm6) FERM BP-7332, and the *Escherichia coli* strain with pUCRm3 under *E. coli* DH5α(pUCRm3) FERM BP-7638.

[0039] The gene of the invention may be used singly, or may be introduced into a microorganism together with another gene or other genes involved in the biosynthesis of coenzyme Q₁₀ for expression thereof. In the latter case, better results can be expected.

[0040] Coenzyme Q₁₀ can be produced by cultivating the transformant obtained in the invention in a medium in the conventional manner and recovering coenzyme Q₁₀ from the cultivation product. In cases where the host microorganism is *Escherichia coli*, LB medium, or M9 medium containing glucose and casamino acids can be used as the medium. For better promoter functioning, such an agent as isopropylthiogalactoside or indolyl-3-acrylic acid, for instance, may be added to the medium. The cultivation is carried out, for example, at 37°C for 17 to 24 hours, if necessary with aeration and/or agitation. In the practice of the invention, the product coenzyme Q₁₀ obtained may be purified or used in the form of a crude product according to the selection duly made depending on the intended use thereof. Coenzyme Q₁₀ can be isolated from the cultivation product by an appropriate combination of per se known methods of separation and/or purification. The per se known methods of separation and/or purification include salting out, solvent precipitation and other methods utilizing the difference in solubility, dialysis, ultrafiltration, gel filtration, (SDS-)polyacrylamide gel electrophoresis and other methods mainly utilizing the difference in molecular weight, ion exchange chromatography and other methods utilizing the difference in charge, affinity chromatography and other methods utilizing specific affinity, reversed phase high-performance liquid chromatography and other methods utilizing the difference in hydrophobicity, isoelectric focusing and other methods utilizing the difference in isoelectric point, among others.

[0041] The field of utilization of coenzyme Q₁₀ obtained in the present invention is not particularly restricted but it may be judiciously used as a drug, among others.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042]

Fig. 1 is a restriction enzyme map of the expression vector pNTRm2.

Fig. 2 is a restriction enzyme map of the expression vector pNTRm6.

Fig. 3 shows HPLC analysis charts for the host and transformant products.

Fig. 4 is a restriction enzyme map of the expression vector pUCRm3.

Fig. 5 shows HPLC analysis charts for the products in the host for the expression vector pUCRm3 and in the transformant.

BEST MODES FOR CARRYING OUT THE INVENTION

[0043] The following examples illustrate the present invention in more detail. These examples are, however, by no means limitative of the scope of the invention.

(Example 1)

[0044] The chromosomal DNA of *Rhodotorula minuta* IFO 0387 was prepared by the method of C. S. Hoffman et al. (Gene, 57 (1987), 267-272). Based on the homology with the known long-chain prenol diphosphate synthase gene, primers for use in PCR, namely DPS-1 (5'-AAGGATCCTNYTNCAYGAYGAYGT-3') and DPS-1 1AS (5'-ARYT-GNADRAAYTCNCC-3'), were designed. In these sequences, R represents A or G, Y represents C or T, and N represents G, A, T or C. Using these, a PCR cycle of 94°C, 1 minute → 43°C, 2 minutes → 72°C, 2 minutes, were repeated 40 times after 3 minutes of heat treatment at 94°C (ExTaq, product of Takara, being used as the enzyme), followed by 1.2% agarose gel electrophoresis.

[0045] The thus-obtained fragment, about 220 bp in size, was purified by excising the corresponding gel portion from the gel and then treating with a DNA extraction kit (Sephaglas (trademark) BrandPrep Kit, product of Amersham Pharmacia Biotech), and the purified fragment was cloned into a vector for expression in *Escherichia coli* using a PCR product direct cloning kit (pT7 BlueT-Vector Kit, product of NOVAGEN) to give pT7-RmDPS. The DNA base sequence was determined by carrying out the reaction on a DNA sequencer (model 377, product of PerkinElmer) using a DNA sequencing kit (product of PerkinElmer, ABI PRISM (trademark) BigDye (trademark) Terminator Cycle Sequence Ready

Reaction Kit with AmptiTaq (registered trademark) DNA polymerase, FS) and according to the manual attached thereto. As a result, a sequence covering the 823rd to 1029th bases of the base sequence shown under SEQ ID NO:1 in the sequence listing was obtained. The sequence "GDPELLARA", which is a characteristic region of the long-chain prenyl chain-containing prenyl diphosphate synthase, could be found in the sequence translated from the base sequence determined in the above manner. It was therefore estimated that the sequence obtained be part of the decaprenyl diphosphate synthase gene.

(Example 2)

[0046] Using 0.03 µg of the pT7-RmDPS vector DNA having the 220 bp DNA fragment supposed to be part of the decaprenyl diphosphate synthase gene of *Rhodotorula minuta* IFO 0387 and using the PCR primers Rm-1S (having the sequence 5'-GCCATGAGGAGAGCACAAGCG-3') and Rm-2AS (having the sequence 5'-CACGGAG-GCTACTAGCTCGAC-3'), PCR (94°C, 3 minutes → (94°C, 30 seconds → 55°C, 30 seconds → 72°C, 1 minute) x 25 cycles → 72°C/ 5 minutes → 4°C) was carried out, followed by 1.2% agarose (product of Takara Shuzo Co., Ltd.) gel electrophoresis. After excision of the corresponding portion from the gel, a fragment, about 145 bp in size, was purified using a DNA extraction kit (Sephaglas (trademark) BrandPrep Kit, product of Amersham Pharmacia Biotech). About 100 ng of this DNA fragment was subjected to chemiluminescence labeling using an ECL direct nucleic acid labeling system (product of Amersham Pharmacia Biotech).

(Example 3)

[0047] The chromosomal DNA of *Rhodotorula minuta* IFO 0387 was cleaved with the restriction enzyme EcoRI, followed by 0.8% agarose gel electrophoresis. The gel was denatured with an alkali (0.5 M NaOH, 1.5 M NaCl) and then neutralized (0.5 M Tris-HCl (pH 7.5), 1.5 M NaCl), a Hibond N+ filter (product of Amersham) was laid on the gel, and southern transfer was effected overnight using 20 x SSC. The filters was dried and baked at 80°C for 2 hours and, thereafter, southern hybridization and detection were carried out using an ECL direct nucleic acid labeling/detection system (product of Amersham Pharmacia Biotech). Thus, using a Gold hybridization solution (product of Amersham Pharmacia Biotech), prehybridization was carried out at 42°C for 1 hour.

[0048] The chemiluminescence-labeled probe was heated at 95°C for 5 minutes, then quenched in ice, and added to the prehybridization for the prehybridized filter, and hybridization was carried out at 42°C for 22 hours. This filter was washed with two portions of a 0.5 x SSC solution containing 6 M urea and 0.4% SDS at 42°C for 20 minutes (for each portion) and then with two portions of a 2 x SSC solution at room temperature for 5 minutes (for each portion). This filter was immersed in an enhanced chemiluminescence reagent (product of Amersham Pharmacia Biotech) and brought into close contact with an X ray film for exposure thereof, and black bands resulting from exposure were detected. As a result, strong hybridization with a fragment, about 5.5 kbp in size, resulting from the cleavage with the restriction enzyme EcoRI was detected.

(Example 4)

[0049] The chromosomal DNA of *Rhodotorula minuta* IFO 0387 was cleaved with the restriction enzyme EcoRI, followed by 0.8% agarose gel electrophoresis. A DNA fragment for use in cloning was prepared by excising the gel portion containing a DNA fragment in the vicinity of about 5.5 kbp in size and purifying the fragment. Using a λ-ZAPII phage kit (product of Stratagene), this DNA fragment was inserted into the phage at its EcoRI site, followed by packaging using an *in vitro* packaging kit (product of Amersham). *Escherichia coli* XL1-Blue MRF' was infected with the phage and layered onto an NZY plate medium (5 g/L NaCl, 2 g/L MgSO₄·7H₂O, 5 g/L yeast extract, 10 g/L NZ amine, 18 g/L agar, pH 7.5), together with an NZY soft agar medium (same as the NZY plate medium except for the content of agar, which was 8 g/L), for plaque formation. The plaques were transferred onto a Hibond N+ filter (product of Amersham), denatured with an alkali (0.5 M NaOH, 1.5 M NaCl), neutralized (0.5 M Tris-HCl (pH 7.5), 1.5 M NaCl), dried, and baked at 80°C for 2 hours.

[0050] Using 6 filters after baking as prepared in the above manner, prehybridization and hybridization using the chemiluminescence-labeled probe were carried out in the same manner as in Example 3, and the filters were washed. After drying, the filters were brought into close contact with an X ray film for exposure of the same, and the phage plaques corresponding to black spots resulting from exposure were isolated. *Escherichia coli* was infected with the phages of the thus-isolated plaques in the same manner as mentioned above for plaque formation. The plaques obtained were transferred onto a filter and again subjected to hybridization for confirmation. Seven phage strains could be selected.

[0051] *Escherichia coli* SOLR in the λ-ZAPII phage kit (product of Stratagene) was infected with each of those phages in a suspension form, together with the helper phage, and a phagemid was prepared *in vitro*. The above phagemid

contained an insert fragment of about 5.5 kbp and, when PCR was carried out using the primers Rm-1S and Rm-2AS, the 145 bp DNA fragment could be detected. The DNA base sequence was determined by carrying out the reactions on a DNA sequencer (model 377, product of PerkinElmer, Inc.) using the internal primers Rm-1S and Rm-2AS and using a DNA sequencing kit (product of PerkinElmer, Inc., ABI PRISM (trademark) BigDye (trademark) Terminator Cycle Sequence Ready Reaction Kit with AmptiQ (registered trademark) DNA polymerase, FS) according to the manual attached thereto. As a result of repeated sequencing using primers prepared based on the sequence revealed by preceding sequencing, the whole sequence of the decaprenyl diphosphate synthase gene of *Rhodotorula minuta* IFO 0387 could be revealed. Thus, the base sequence of a DNA of about 1.6 kbp was determined. The results are shown under SEQ ID NO:1 in the sequence listing. The amino acid sequence deduced from this DNA sequence is shown under SEQ ID NO:2.

(Example 5)

[0052] For excising the decaprenyl diphosphate synthase-encoding gene portion from the phagemid DNA prepared, PCR was carried out in the same manner as in Example 2 using two synthetic DNA primers designated RM-1 (having the sequence 5'-ATCATATGATGCACCGACAAGCT-3') and Rm-CE2 (having the sequence 5'-AAGAATTCCTACTTT-GTTCGGTTGAGCACAG-3'). The amplification product was cleaved with the restriction enzymes *NdeI* and *EcoRI*, and the cleavage product was inserted into a vector for expression, pUCNT (described in WO 94/03613) to give a decaprenyl diphosphate synthase gene expression vector, pNTRm2. The restriction enzyme map of the thus-obtained expression vector pNTRm2 is shown in Fig. 1. The symbol DPS stands for the coding region of the decaprenyl diphosphate synthase gene.

(Example 6)

[0053] The thus-constructed decaprenyl diphosphate synthase gene expression vector pNTRm2 was introduced into *Escherichia coli* HB101, the microorganisms were shake-cultured overnight in 10 mL of LB medium at 37°C, and cells were harvested by centrifugation (3,000 revolutions, 20 minutes).

[0054] The cells were suspended in 1 mL of a 3% aqueous solution of sulfuric acid and, after 30 minutes of heat treatment at 120°C, 2 mL of a 14% aqueous solution of sodium hydroxide was added, followed by further 15 minutes of heat treatment at 120°C. To the thus-treated suspension was added 3 mL of hexane-isopropanol (10:2) for effecting extraction. After centrifugation, 1.5 mL of the organic solvent layer was separated, and the solvent was evaporated to dryness under reduced pressure conditions. The residue was dissolved in 200 µl of ethanol, and 20 µl of the solution was analyzed by high-performance liquid chromatography (using LC-10A, product of Shimadzu Corp.). For separation, a reversed phase column (YMC-pack ODS-A, 250 x 4.6 mm, 5-5 µm, 120A) was used, together with ethanol-methanol (2:1) as the mobile phase solvent. The coenzyme Q₁₀ formed was detected based on the absorbance at the wavelength 275 nm. The results are shown in Fig. 2. As shown in Fig. 2, it was revealed that, upon introduction of the decaprenyl diphosphate synthase gene for expression of Q₁₀, the transformant *Escherichia coli* strain was now possible to produce coenzyme Q₁₀, which is originally not produced in *Escherichia coli*.

[0055] The thus-obtained recombinant *Escherichia coli* HB101(pNTRm2) has been deposited, under the Budapest Treaty, with the National Institute of Advanced Industrial Science and Technology International Patent Organism Depository (Central 6, 1-1-1 Higashi, Tsukuba, Ibaraki, Japan) as of October 19, 2000 (deposition/accession No. FERM BP-7333).

(Example 7)

[0056] For eliminating the mitochondrial transitional sequence characteristic of eukaryotes from the sequence under SEQ ID NO:1 in order to attain abundant expression in prokaryotes, PCR was carried out in the same manner as in Example 2 using two synthetic DNA primers designated Rm-4 (having the sequence 5'-ATCATATGAATATTCGAC-CCACTCCAAGCT-3') and Rm-CE2 (having the sequence 5'-AAGAATTCCTACTTTGTTcGGTTGAGCACAG-3'). The thus-amplified 1.3 kbp fragment was cleaved with the restriction enzymes *NdeI* and *NheI*, and the thus-prepared fragment, about 600 bp in size, was recombined to the major fragment of pNTRm2 as obtained by digestion with the restriction enzymes *NdeI* and *NheI* to construct pNTRmSsp. Further, PCR was carried out in the same manner as in Example 2 using two synthetic DNA primers designated RM-1 (having the sequence 5'-ATCATATGATGCAC-CGACAAGCT-3') and RM-6R (having the sequence 5'-ACAATATTGTATTGAGGGCATTGGGCGACTGC-3') for amplifying a fragment, about 100 bp in size, resulting from deletion of the N portion. The fragment was cleaved with the restriction enzymes *NdeI* and *SspI*, and the resulting fragment was recombined to the major fragment of pNTRmSsp as resulting from digestion with the restriction enzymes *NdeI* and *SspI* to construct pNTRm6.

(Example 8)

[0057] The thus-constructed decaprenyl diphosphate synthase gene expression vector pNTRm6 was introduced into *Escherichia coli* HB101, the microorganisms were shake-cultured overnight in 10 mL of LB medium at 37°C, and cells were harvested by centrifugation (3,000 revolutions, 20 minutes).

[0058] The cells were suspended in 1 mL of a 3% aqueous solution of sulfuric acid and, after 30 minutes of heat treatment at 120°C, 2 mL of a 14% aqueous solution of sodium hydroxide was added, followed by further 15 minutes of heat treatment at 120°C. To the thus-treated suspension was added 3 mL of hexane-isopropanol (10:2) for effecting extraction. After centrifugation, 1.5 mL of the organic solvent layer was separated, and the solvent was evaporated to dryness under reduced pressure conditions. The residue was dissolved in 200 µl of ethanol, and 20 µl of the solution was analyzed by high-performance liquid chromatography (using LC-10A, product of Shimadzu Corp.). For separation, a reversed phase column (YMC-pack ODS-A, 250 x 4.6 mm, S-5 µm, 120A) was used, together with ethanol-methanol (2:1) as the mobile phase solvent. The coenzyme Q₁₀ formed was detected based on the absorbance at the wavelength 275 nm. The results are shown in Fig. 3. As shown in Fig. 3, it was revealed that, upon introduction of the decaprenyl diphosphate synthase gene for expression thereof, coenzyme Q₁₀, which is originally not produced in *Escherichia coli*, could now be produced in the transformant and that conversion could be attained so as to attain coenzyme Q₁₀ production in significantly larger amounts as compared with the *Escherichia coli* strain transformed with pNTRm2.

[0059] The thus-obtained recombinant *Escherichia coli* HB101(pNTRm6) has been deposited, under the Budapest Treaty, with the National Institute of Advanced Industrial Science and Technology International Patent Organism Depository (Central 6, 1-1-1 Higashi, Tsukuba, Ibaraki, Japan) as of October 19, 2000 (deposition/accession No. FERM BP-7332).

(Example 9)

[0060] For eliminating the mitochondrial transitional sequence characteristic of eukaryotes from the sequence under SEQ ID NO:1 in order to attain abundant expression in prokaryotes, PCR was carried out in the same manner as in Example 2 using two synthetic DNA primers designated RmNEco (having the sequence 5'-ACGAATTCGATGATCTTC-GACCCACTCCAAC-3') and Rm-CE2 (having the sequence 5'-AAGAATTCCTACTTTGTTGCGTTGAGCACAG-3'), with pNTRm2 as the template. The thus-amplified 1.2 kbp fragment was cleaved with the restriction enzymes *Bam*HI and *Eco*RI, and the thus-prepared fragment was joined to the major fragment of pUC18 as obtained by digestion with the restriction enzymes *Bam*HI and *Eco*RI to construct pUCRm3.

(Example 10)

[0061] The thus-constructed decaprenyl diphosphate synthase gene expression vector pUCRm3 was introduced into *Escherichia coli* DH5α, the microorganisms were shake-cultured overnight in 10 mL of LB medium at 37°C, and cells were harvested by centrifugation (3,000 revolutions, 20 minutes).

[0062] The cells were suspended in 1 mL of a 3% aqueous solution of sulfuric acid and, after 30 minutes of heat treatment at 120°C, 2 mL of a 14% aqueous solution of sodium hydroxide was added, followed by further 15 minutes of heat treatment at 120°C. To the thus-treated suspension was added 3 mL of hexane-isopropanol (10:2) for effecting extraction. After centrifugation, 1.5 mL of the organic solvent layer was separated, and the solvent was evaporated to dryness under reduced pressure conditions. The residue was dissolved in 200 µl of ethanol, and 20 µl of the solution was analyzed by high-performance liquid chromatography (using LC-10A, product of Shimadzu Corp.). For separation, a reversed phase column (YMC-pack ODS-A, 250 x 4.6 mm, S-5 µm, 120A) was used, together with ethanol-methanol (2:1) as the mobile phase solvent. The coenzyme Q₁₀ formed was detected based on the absorbance at the wavelength 275 nm. The results are shown in Fig. 3. As shown in Fig. 5, it was revealed that, upon introduction of the decaprenyl diphosphate synthase gene for expression thereof, coenzyme Q₁₀, which is originally not produced in *Escherichia coli*, could now be produced in the transformant and that conversion could be attained so as to attain coenzyme Q₁₀ production in significantly larger amounts as compared with the *Escherichia coli* strains transformed with pNTRm2 and pNTRm6, respectively.

[0063] The thus-obtained recombinant *Escherichia coli* DH5α (pUCRm3) has been deposited, under the Budapest Treaty, with the National Institute of Advanced Industrial Science and Technology International Patent Organism Depository (Central 6, 1-1-1 Higashi, Tsukuba, Ibaraki, Japan) as of June 22, 2001 (deposition/accession No. FERM BP-7638).

INDUSTRIAL APPLICABILITY

[0064] A gene encoding decaprenyl diphosphate synthase, which is the key enzyme in the biosynthesis of coenzyme

Q₁₀ was isolated from a fungal species belonging to the genus *Rhodotorula* and it was sequenced. This could successfully be introduced in *Escherichia coli* for expression thereof. Furthermore, improvements in gene sequence successfully resulted in production of coenzyme Q₁₀ in significant amounts. By using the method of the invention, it becomes possible to efficiently produce coenzyme Q₁₀, which is in use as a drug, among others.

5

10

15

20

25

30

35

40

45

50

55

SEQUENCE LISTING

5 <110> KANEKA CORPORATION

10 <120> Process for producing coenzyme Q₁₀

<130> T640.W01/QX-GT3

15 <150> JP2000-352940

<151> 2000-11-20

20 <160> 6

<210> 1

25 <211> 1614

<212> DNA

<213> Rhodotorula minuta

30 <400> 1

atg atg cac cga caa gct gca tgt aga gtg tgc agt cac act tgc agt 48

35 MET MET His Arg Gln Ala Ala Cys Arg Val Cys Ser His Thr Cys Ser

1

5

10

15

40 cgc ccg aat gcc ctg ttg gcc ggc ata tat gga cca tca tca gca tca 96

Arg Pro Asn Ala Leu Leu Ala Gly Ile Tyr Gly Pro Ser Ser Ala Ser

20

25

30

45 tca tcg acg acg acg act tca aca tca aga agc aac cac aac aac 144

Ser Ser Thr Thr Thr Thr Thr Ser Thr Ser Arg Ser Asn His Asn Asn

35

40

45

50 agt gta cga ttc aag cat tcg ttg agt aat act agc aaa cca gct gcc 192

Ser Val Arg Phe Lys His Ser Leu Ser Asn Thr Ser Lys Pro Ala Ala

55 50

55

60

5 aga tcg aca tcc act tcc gct cct gct ctc tct ccc tct tct tca aca 240
 Arg Ser Thr Ser Thr Ser Ala Pro Ala Leu Ser Pro Ser Ser Ser Thr
 65 70 75 80

10 agc gat cct caa tct tcc tca tca cca tcc tct tcc tct tct tct tct 288
 Ser Asp Pro Gln Ser Ser Ser Ser Pro Ser Ser Ser Ser Ser Ser Ser
 85 90 95

15 tct att ctt cct gac ttt ttg aga tca cca tta tcg tcc tcg tcc tcc 336
 Ser Ile Leu Pro Asp Phe Leu Arg Ser Pro Leu Ser Ser Ser Ser Ser
 100 105 110

20 tca tcc tcg aca agt agc tct tca tca tca tcg tca agc aat cgc tcc 384
 Ser Ser Ser Thr Ser Ser Ser Ser Ser Ser Ser Ser Ser Ser Asn Arg Ser
 115 120 125

25 aaa aac act aac agc aat aca atc ttc gac cca ctc caa ctc gta ggc 432
 Lys Asn Thr Asn Ser Asn Thr Ile Phe Asp Pro Leu Gln Leu Val Gly
 130 135 140

30 aat gaa ctg tca agt ctc cgg tca aac gtc caa gcc cta ctg gga tca 480
 Asn Glu Leu Ser Ser Leu Arg Ser Asn Val Gln Ala Leu Leu Gly Ser
 145 150 155 160

35 ggt cat ccc gcc cta gac acg ata gca aag tac tac ttc caa gcg gag 528
 Gly His Pro Ala Leu Asp Thr Ile Ala Lys Tyr Tyr Phe Gln Ala Glu
 165 170 175

40 ggc aaa cat att cgg cct atg atc gtt ctt ctc atg tcc caa gcc aca 576
 Gly Lys His Ile Arg Pro MET Ile Val Leu Leu MET Ser Gln Ala Thr
 180 185 190

45 aac ggt cta gcg ccc ggg ttt gaa gaa cgc tca aaa ttg gaa cta tca 624
 Asn Gly Leu Ala Pro Gly Phe Glu Glu Arg Ser Lys Leu Glu Leu Ser

55

195

200

205

5 ggt cgg aaa cag act gat ccc tcc agg tca atc aat gat cct ctc gaa 672
 Gly Arg Lys Gln Thr Asp Pro Ser Arg Ser Ile Asn Asp Pro Leu Glu
 210 215 220

10 gtg aaa gca gat gag ata ctc aac gat tcg aat ccc tct tcg ttc gct 720
 Val Lys Ala Asp Glu Ile Leu Asn Asp Ser Asn Pro Ser Ser Phe Ala
 225 230 235 240

15 gcg agc tcc tct tcg ccg ctc gat agc atg ccg tcc acg tcg aat gtc 768
 Ala Ser Ser Ser Ser Pro Leu Asp Ser MET Pro Ser Thr Ser Asn Val
 245 250 255

20 cta ccc tcg caa cga cgc ctc gcg gaa atc acc gaa atg atc cac gta 816
 Leu Pro Ser Gln Arg Arg Leu Ala Glu Ile Thr Glu MET Ile His Val
 260 265 270

25 gct tcg cta ttg cac gac gat gtc ata gac ggt tca gcc atg agg aga 864
 Ala Ser Leu Leu His Asp Asp Val Ile Asp Gly Ser Ala MET Arg Arg
 275 280 285

30 gca caa gcg tcc gcc ccc gct gca ttc ggg aac aag atc tcg gtg ctg 912
 Ala Gln Ala Ser Ala Pro Ala Ala Phe Gly Asn Lys Ile Ser Val Leu
 290 295 300

35 ggc ggg gat ttc ctc ctc gct cgt gct tcg ctg tac ctc tcc cga cta 960
 Gly Gly Asp Phe Leu Leu Ala Arg Ala Ser Leu Tyr Leu Ser Arg Leu
 305 310 315 320

40 ggg agc aac gag gtc gtc gag cta gta gcc tcc gtg cta gct aat cta 1008
 Gly Ser Asn Glu Val Val Glu Leu Val Ala Ser Val Leu Ala Asn Leu
 325 330 335

45 gta gag ggc gaa gtc atg cag atc aag gga aat gct cct gaa agc aat 1056

Val Glu Gly Glu Val MET Gln Ile Lys Gly Asn Ala Pro Glu Ser Asn
 340 345 350

gca agc gga agc aaa gag gta gca gtg cac aga ttg acc ccg gaa att 1104
 Ala Ser Gly Ser Lys Glu Val Ala Val His Arg Leu Thr Pro Glu Ile
 355 360 365

ttc gaa cat tat atg aag aag aca tac ttg aag acc gca agt ctc atc 1152
 Phe Glu His Tyr MET Lys Lys Thr Tyr Leu Lys Thr Ala Ser Leu Ile
 370 375 380

gcg aaa tcg aca aga gcg acc act atc ctc ggt gga gca ggc gag aaa 1200
 Ala Lys Ser Thr Arg Ala Thr Thr Ile Leu Gly Gly Ala Gly Glu Lys
 385 390 395 400

cag ggg tgg ata gag ggc gag cgc ata aaa gac att gcg tac tcg tac 1248
 Gln Gly Trp Ile Glu Gly Glu Arg Ile Lys Asp Ile Ala Tyr Ser Tyr
 405 410 415

ggt cgc aat cta ggt att got ttc cag ctc gtc gac gat cta cta gat 1296
 Gly Arg Asn Leu Gly Ile Ala Phe Gln Leu Val Asp Asp Leu Leu Asp
 420 425 430

ttc aca gct aca gac gcg caa ttc ggc aag ccc tca cag ggt gca gat 1344
 Phe Thr Ala Thr Asp Ala Gln Phe Gly Lys Pro Ser Gln Gly Ala Asp
 435 440 445

ctg aag ctc ggt ctc gca act gcg ccc gcg ctg tac gca tgg gaa gag 1392
 Leu Lys Leu Gly Leu Ala Thr Ala Pro Ala Leu Tyr Ala Trp Glu Glu
 450 455 460

ttc ccg gag atg ggc cag atg att ctc cgc aag ttt gag aac gaa ggc 1440
 Phe Pro Glu MET Gly Gln MET Ile Leu Arg Lys Phe Glu Asn Glu Gly
 465 470 475 480

gat gtc gaa act gcc agg aat cta gta aga aag tca gct gga ccg gaa 1488
 Asp Val Glu Thr Ala Arg Asn Leu Val Arg Lys Ser Ala Gly Pro Glu

5 485 490 495

aag acc gtg aaa ttg gcg gaa aaa cat gcc gca ctc gca atg gag gcc 1536
 Lys Thr Val Lys Leu Ala Glu Lys His Ala Ala Leu Ala MET Glu Ala

10 500 505 510

ctg cag gga ttg ccg gag tcg gac gct aga gaa gcg ctc gaa ggc ctg 1584
 Leu Gln Gly Leu Pro Glu Ser Asp Ala Arg Glu Ala Leu Glu Gly Leu

15 515 520 525

acc aag act gtg ctc aac cga aca aag tag 1614
 Thr Lys Thr Val Leu Asn Arg Thr Lys

20 530 535

25 <210> 2

<211> 537

30 <212> PRT

<213> Rhodotorula minuta

35 <400> 2

MET MET His Arg Gln Ala Ala Cys Arg Val Cys Ser His Thr Cys
 1 5 10 15

40 Ser Arg Pro Asn Ala Leu Leu Ala Gly Ile Tyr Gly Pro Ser Ser
 20 25 30

45 Ala Ser Ser Ser Thr Thr Thr Thr Thr Ser Thr Ser Arg Ser Asn
 35 40 45

50 His Asn Asn Ser Val Arg Phe Lys His Ser Leu Ser Asn Thr Ser
 50 55 60

55

	Lys Pro Ala Ala Arg Ser Thr Ser Thr Ser Ala Pro Ala Leu Ser	
	65	70 75
5		
	Pro Ser Ser Ser Thr Ser Asp Pro Gln Ser Ser Ser Ser Pro Ser	
	80	85 90
10		
	Ser Ser Ser Ser Ser Ser Ser Ile Leu Pro Asp Phe Leu Arg Ser	
	95	100 105
15		
	Pro Leu Ser Ser Ser Ser Ser Ser Ser Ser Thr Ser Ser Ser Ser	
	110	115 120
20		
	Ser Ser Ser Ser Ser Asn Arg Ser Lys Asn Thr Asn Ser Asn Thr	
	125	130 135
25		
	Ile Phe Asp Pro Leu Gln Leu Val Gly Asn Glu Leu Ser Ser Leu	
	140	145 150
30		
	Arg Ser Asn Val Gln Ala Leu Leu Gly Ser Gly His Pro Ala Leu	
	155	160 165
35		
	Asp Thr Ile Ala Lys Tyr Tyr Phe Gln Ala Glu Gly Lys His Ile	
	170	175 180
40		
	Arg Pro MET Ile Val Leu Leu MET Ser Gln Ala Thr Asn Gly Leu	
	185	190 195
45		
	Ala Pro Gly Phe Glu Glu Arg Ser Lys Leu Glu Leu Ser Gly Arg	
	200	205 210
50		
	Lys Gln Thr Asp Pro Ser Arg Ser Ile Asn Asp Pro Leu Glu Val	
	215	220 225
55		
	Lys Ala Asp Glu Ile Leu Asn Asp Ser Asn Pro Ser Ser Phe Ala	
	230	235 240

5	Ala Ser Ser Ser Ser Pro Leu Asp Ser MET Pro Ser Thr Ser Asn	245	250	255
10	Val Leu Pro Ser Gln Arg Arg Leu Ala Glu Ile Thr Glu MET Ile	260	265	270
15	His Val Ala Ser Leu Leu His Asp Asp Val Ile Asp Gly Ser Ala	275	280	285
20	MET Arg Arg Ala Gln Ala Ser Ala Pro Ala Ala Phe Gly Asn Lys	290	295	300
25	Ile Ser Val Leu Gly Gly Asp Phe Leu Leu Ala Arg Ala Ser Leu	305	310	315
30	Tyr Leu Ser Arg Leu Gly Ser Asn Glu Val Val Glu Leu Val Ala	320	325	330
35	Ser Val Leu Ala Asn Leu Val Glu Gly Glu Val MET Gln Ile Lys	335	340	345
40	Gly Asn Ala Pro Glu Ser Asn Ala Ser Gly Ser Lys Glu Val Ala	350	355	360
45	Val His Arg Leu Thr Pro Glu Ile Phe Glu His Tyr MET Lys Lys	365	370	375
50	Thr Tyr Leu Lys Thr Ala Ser Leu Ile Ala Lys Ser Thr Arg Ala	380	385	390
55	Thr Thr Ile Leu Gly Gly Ala Gly Glu Lys Gln Gly Trp Ile Glu	395	400	405
	Gly Glu Arg Ile Lys Asp Ile Ala Tyr Ser Tyr Gly Arg Asn Leu			

	410	415	420
5	Gly Ile Ala Phe Gln Leu Val Asp Asp Leu Leu Asp Phe Thr Ala		
	425	430	435
10	Thr Asp Ala Gln Phe Gly Lys Pro Ser Gln Gly Ala Asp Leu Lys		
	440	445	450
15	Leu Gly Leu Ala Thr Ala Pro Ala Leu Tyr Ala Trp Glu Glu Phe		
	455	460	465
20	Pro Glu MET Gly Gln MET Ile Leu Arg Lys Phe Glu Asn Glu Gly		
	470	475	480
25	Asp Val Glu Thr Ala Arg Asn Leu Val Arg Lys Ser Ala Gly Pro		
	485	490	495
30	Glu Lys Thr Val Lys Leu Ala Glu Lys His Ala Ala Leu Ala MET		
	500	505	510
35	Glu Ala Leu Gln Gly Leu Pro Glu Ser Asp Ala Arg Glu Ala Leu		
	515	520	525
40	Glu Gly Leu Thr Lys Thr Val Leu Asn Arg Thr Lys		
	530	535	
45	<210> 3		
	<211> 1278		
	<212> DNA		
	<213> Rhodotorula minuta		
50	<400> 3		
55	atg atg cac cga caa gct gca tgt aga gtg tgc agt cac act tgc agt	48	
	MET MET His Arg Gln Ala Ala Cys Arg Val Cys Ser His Thr Cys Ser		

1

5

10

15

5 cgc ccg aat gcc ctc aat aca atc ttc gac cca ctc caa ctc gta ggc 96

Arg Pro Asn Ala Leu Asn Thr Ile Phe Asp Pro Leu Gln Leu Val Gly

20

25

30

10

aat gaa ctg tca agt ctc cgg tca aac gtc caa gcc cta ctg gga tca 144

Asn Glu Leu Ser Ser Leu Arg Ser Asn Val Gln Ala Leu Leu Gly Ser

35

40

45

15

ggc cat ccc gcc cta gac acg ata gca aag tac tac ttc caa gcg gag 192

Gly His Pro Ala Leu Asp Thr Ile Ala Lys Tyr Tyr Phe Gln Ala Glu

50

55

60

20

ggc aaa cat att cgg cct atg atc gtt ctt ctc atg tcc caa gcc aca 240

Gly Lys His Ile Arg Pro MET Ile Val Leu Leu MET Ser Gln Ala Thr

65

70

75

80

25

30 aac ggt cta gcg ccc ggg ttt gaa gaa cgc tca aaa ttg gaa cta tca 288

Asn Gly Leu Ala Pro Gly Phe Glu Glu Arg Ser Lys Leu Glu Leu Ser

85

90

95

35

ggc cgg aaa cag act gat ccc tcc agg tca atc aat gat cct ctc gaa 336

Gly Arg Lys Gln Thr Asp Pro Ser Arg Ser Ile Asn Asp Pro Leu Glu

100

105

110

40

gtg aaa gca gat gag ata ctc aac gat tcg aat ccc tct tcg ttc gct 384

Val Lys Ala Asp Glu Ile Leu Asn Asp Ser Asn Pro Ser Ser Phe Ala

115

120

125

45

gcg agc tcc tct tcg ccg ctc gat agc atg ccg tcc acg tcg aat gtc 432

Ala Ser Ser Ser Ser Pro Leu Asp Ser MET Pro Ser Thr Ser Asn Val

130

135

140

50

55 cta ccc tcg caa cga cgc ctc gcg gaa atc acc gaa atg atc cac gta 480

Leu Pro Ser Gln Arg Arg Leu Ala Glu Ile Thr Glu MET Ile His Val
 145 150 155 160

gct tcg cta ttg cac gac gat gtc ata gac ggt tca gcc atg agg aga 528
 Ala Ser Leu Leu His Asp Asp Val Ile Asp Gly Ser Ala MET Arg Arg
 165 170 175

gca caa gcg tcc gcc ccc gct gca ttc ggg aac aag atc tcg gtg ctg 576
 Ala Gln Ala Ser Ala Pro Ala Ala Phe Gly Asn Lys Ile Ser Val Leu
 180 185 190

ggc ggg gat ttc ctc ctc gct cgt gct tcg ctg tac ctc tcc cga cta 624
 Gly Gly Asp Phe Leu Leu Ala Arg Ala Ser Leu Tyr Leu Ser Arg Leu
 195 200 205

ggg agc aac gag gtc gtc gag cta gta gcc tcc gtg cta gct aat cta 672
 Gly Ser Asn Glu Val Val Glu Leu Val Ala Ser Val Leu Ala Asn Leu
 210 215 220

gta gag ggc gaa gtc atg cag atc aag gga aat gct cct gaa agc aat 720
 Val Glu Gly Glu Val MET Gln Ile Lys Gly Asn Ala Pro Glu Ser Asn
 225 230 235 240

gca agc gga agc aaa gag gta gca gtg cac aga ttg acc ccg gaa att 768
 Ala Ser Gly Ser Lys Glu Val Ala Val His Arg Leu Thr Pro Glu Ile
 245 250 255

ttc gaa cat tat atg aag aag aca tac ttg aag acc gca agt ctc atc 816
 Phe Glu His Tyr MET Lys Lys Thr Tyr Leu Lys Thr Ala Ser Leu Ile
 260 265 270

gcg aaa tcg aca aga gcg acc act atc ctc ggt gga gca ggc gag aaa 864
 Ala Lys Ser Thr Arg Ala Thr Thr Ile Leu Gly Gly Ala Gly Glu Lys
 275 280 285

5 cag ggg tgg ata gag ggc gag cgc ata aaa gac att gcg tac tcg tac 912
 Gln Gly Trp Ile Glu Gly Glu Arg Ile Lys Asp Ile Ala Tyr Ser Tyr
 290 295 300

10 ggt cgc aat cta ggt att gct ttc cag ctc gtc gac gat cta cta gat 960
 Gly Arg Asn Leu Gly Ile Ala Phe Gln Leu Val Asp Asp Leu Leu Asp
 305 310 315 320

15 ttc aca gct aca gac gcg caa ttc ggc aag ccc tca cag ggt gca gat 1008
 Phe Thr Ala Thr Asp Ala Gln Phe Gly Lys Pro Ser Gln Gly Ala Asp
 325 330 335

20 ctg aag ctc ggt ctc gca act gcg ccc gcg ctg tac gca tgg gaa gag 1056
 Leu Lys Leu Gly Leu Ala Thr Ala Pro Ala Leu Tyr Ala Trp Glu Glu
 340 345 350

25 ttc cgg gag atg ggc cag atg att ctc cgc aag ttt gag aac gaa ggc 1104
 Phe Pro Glu MET Gly Gln MET Ile Leu Arg Lys Phe Glu Asn Glu Gly
 30 355 360 365

35 gat gtc gaa act gcc agg aat cta gta aga aag tca gct gga ccg gaa 1152
 Asp Val Glu Thr Ala Arg Asn Leu Val Arg Lys Ser Ala Gly Pro Glu
 370 375 380

40 aag acc gtg aaa ttg gcg gaa aaa cat gcc gca ctc gca atg gag gcc 1200
 Lys Thr Val Lys Leu Ala Glu Lys His Ala Ala Leu Ala MET Glu Ala
 385 390 395 400

45 ctg cag gga ttg ccg gag tog gac gct aga gaa gcg ctc gaa ggc ctg 1248
 Leu Gln Gly Leu Pro Glu Ser Asp Ala Arg Glu Ala Leu Glu Gly Leu
 405 410 415

50 acc aag act gtg ctc aac cga aca aag tag 1278
 Thr Lys Thr Val Leu Asn Arg Thr Lys
 55 420 425

<210> 4

<211> 425

<212> PRT

<213> Rhodotorula

<400> 4

MET MET His Arg Gln Ala Ala Cys Arg Val Cys Ser His Thr Cys
1 5 10 15

Ser Arg Pro Asn Ala Leu Asn Thr Ile Phe Asp Pro Leu Gln Leu
20 25 30

Val Gly Asn Glu Leu Ser Ser Leu Arg Ser Asn Val Gln Ala Leu
35 40 45

Leu Gly Ser Gly His Pro Ala Leu Asp Thr Ile Ala Lys Tyr Tyr
50 55 60

Phe Gln Ala Glu Gly Lys His Ile Arg Pro MET Ile Val Leu Leu
65 70 75

MET Ser Gln Ala Thr Asn Gly Leu Ala Pro Gly Phe Glu Glu Arg
80 85 90

Ser Lys Leu Glu Leu Ser Gly Arg Lys Gln Thr Asp Pro Ser Arg
95 100 105

Ser Ile Asn Asp Pro Leu Glu Val Lys Ala Asp Glu Ile Leu Asn
110 115 120

Asp Ser Asn Pro Ser Ser Phe Ala Ala Ser Ser Ser Ser Pro Leu
125 130 135

	Asp Ser MET Pro Ser Thr Ser Asn Val Leu Pro Ser Gln Arg Arg	
	140	145 150
5	Leu Ala Glu Ile Thr Glu MET Ile His Val Ala Ser Leu Leu His	
	155	160 165
10	Asp Asp Val Ile Asp Gly Ser Ala MET Arg Arg Ala Gln Ala Ser	
	170	175 180
15	Ala Pro Ala Ala Phe Gly Asn Lys Ile Ser Val Leu Gly Gly Asp	
	185	190 195
20	Phe Leu Leu Ala Arg Ala Ser Leu Tyr Leu Ser Arg Leu Gly Ser	
	200	205 210
25	Asn Glu Val Val Glu Leu Val Ala Ser Val Leu Ala Asn Leu Val	
	215	220 225
30	Glu Gly Glu Val MET Gln Ile Lys Gly Asn Ala Pro Glu Ser Asn	
	230	235 240
35	Ala Ser Gly Ser Lys Glu Val Ala Val His Arg Leu Thr Pro Glu	
	245	250 255
40	Ile Phe Glu His Tyr MET Lys Lys Thr Tyr Leu Lys Thr Ala Ser	
	260	265 270
45	Leu Ile Ala Lys Ser Thr Arg Ala Thr Thr Ile Leu Gly Gly Ala	
	275	280 285
50	Gly Glu Lys Gln Gly Trp Ile Glu Gly Glu Arg Ile Lys Asp Ile	
	290	295 300
55	Ala Tyr Ser Tyr Gly Arg Asn Leu Gly Ile Ala Phe Gln Leu Val	
	305	310 315

Asp Asp Leu Leu Asp Phe Thr Ala Thr Asp Ala Gln Phe Gly Lys
 5 320 325 330

Pro Ser Gln Gly Ala Asp Leu Lys Leu Gly Leu Ala Thr Ala Pro
 10 335 340 345

Ala Leu Tyr Ala Trp Glu Glu Phe Pro Glu MET Gly Gln MET Ile
 15 350 355 360

Leu Arg Lys Phe Glu Asn Glu Gly Asp Val Glu Thr Ala Arg Asn
 20 365 370 375

Leu Val Arg Lys Ser Ala Gly Pro Glu Lys Thr Val Lys Leu Ala
 25 380 385 390

Glu Lys His Ala Ala Leu Ala MET Glu Ala Leu Gln Gly Leu Pro
 30 395 400 405

Glu Ser Asp Ala Arg Glu Ala Leu Glu Gly Leu Thr Lys Thr Val
 35 410 415 420

Leu Asn Arg Thr Lys
 40 425

<210> 5

<211> 1212

<212> DNA

<213> Rhodotorula minuta

<400> 5

atg atc ttc gac cca ctc caa ctc gta ggc aat gaa ctg tca agt ctc 48
 Met Ile Phe Asp Pro Leu Gln Leu Val Gly Asn Glu Leu Ser Ser Leu
 55 1 5 10 15

5 cgg tca aac gtc caa gcc cta ctg gga tca ggt cat ccc gcc cta gac 96
 Arg Ser Asn Val Gln Ala Leu Leu Gly Ser Gly His Pro Ala Leu Asp
 20 25 30

10 acg ata gca aag tac tac ttc caa gcg gag ggc aaa cat att cgg cct 144
 Thr Ile Ala Lys Tyr Tyr Phe Gln Ala Glu Gly Lys His Ile Arg Pro
 35 40 45

15 atg atc gtt ctt ctc atg tcc caa gcc aca aac ggt cta gcg ccc ggg 192
 Met Ile Val Leu Leu Met Ser Gln Ala Thr Asn Gly Leu Ala Pro Gly
 20 50 55 60

25 ttt gaa gaa cgc tca aaa ttg gaa cta tca ggt cgg aaa cag act gat 240
 Phe Glu Glu Arg Ser Lys Leu Glu Leu Ser Gly Arg Lys Gln Thr Asp
 65 70 75 80

30 ccc tcc agg tca atc aat gat cct ctc gaa gtg aaa gca gat gag ata 288
 Pro Ser Arg Ser Ile Asn Asp Pro Leu Glu Val Lys Ala Asp Glu Ile
 85 90 95

35 ctc aac gat tcg aat ccc tot tcg ttc gct gcg agc tcc tct tcg cgg 336
 Leu Asn Asp Ser Asn Pro Ser Ser Phe Ala Ala Ser Ser Ser Ser Pro
 100 105 110

40 ctc gat agc atg ccg tcc acg tcg aat gtc cta ccc tcg caa cga cgc 384
 Leu Asp Ser Met Pro Ser Thr Ser Asn Val Leu Pro Ser Gln Arg Arg
 115 120 125

45 ctc gcg gaa atc acc gaa atg atc cac gta gct tcg cta ttg cac gac 432
 Leu Ala Glu Ile Thr Glu Met Ile His Val Ala Ser Leu Leu His Asp
 50 130 135 140

55 gat gtc ata gac ggt tca gcc atg agg aga gca caa gcg tcc gcc ccc 480
 Asp Val Ile Asp Gly Ser Ala Met Arg Arg Ala Gln Ala Ser Ala Pro

	145	150	155	160	
5	gct gca ttc ggg aac aag atc tcg gtg ctg ggc ggg gat ttc ctc ctc				528
	Ala Ala Phe Gly Asn Lys Ile Ser Val Leu Gly Gly Asp Phe Leu Leu				
		165	170	175	
10	gct cgt gct tcg ctg tac ctc tcc cga cta ggg agc aac gag gtc gtc				576
	Ala Arg Ala Ser Leu Tyr Leu Ser Arg Leu Gly Ser Asn Glu Val Val				
15		180	185	190	
	gag cta gta gcc tcc gtg cta gct aat cta gta gag ggc gaa gtc atg				624
20	Glu Leu Val Ala Ser Val Leu Ala Asn Leu Val Glu Gly Glu Val Met				
		195	200	205	
25	cag atc aag gga aat gct cct gaa agc aat gca agc gga agc aaa gag				672
	Gln Ile Lys Gly Asn Ala Pro Glu Ser Asn Ala Ser Gly Ser Lys Glu				
	210	215	220		
30	gta gca gtg cac aga ttg acc ccg gaa att ttc gaa cat tat atg aag				720
	Val Ala Val His Arg Leu Thr Pro Glu Ile Phe Glu His Tyr Met Lys				
	225	230	235	240	
35	aag aca tac ttg aag acc gca agt ctc atc gcg aaa tcg aca aga gcg				768
	Lys Thr Tyr Leu Lys Thr Ala Ser Leu Ile Ala Lys Ser Thr Arg Ala				
40		245	250	255	
	acc act atc ctc ggt gga gca ggc gag aaa cag ggg tgg ata gag ggc				816
45	Thr Thr Ile Leu Gly Gly Ala Gly Glu Lys Gln Gly Trp Ile Glu Gly				
	260	265	270		
50	gag cgc ata aaa gac att gcg tac tcg tac ggt cgc aat cta ggt att				864
	Glu Arg Ile Lys Asp Ile Ala Tyr Ser Tyr Gly Arg Asn Leu Gly Ile				
	275	280	285		
55	gct ttc cag ctc gtc gac gat cta cta gat ttc aca gct aca gac gcg				912

Ala Phe Gln Leu Val Asp Asp Leu Leu Asp Phe Thr Ala Thr Asp Ala
 290 295 300

5

caa ttc ggc aag ccc tca cag ggt gca gat ctg aag ctc ggt ctc gca 960
 Gln Phe Gly Lys Pro Ser Gln Gly Ala Asp Leu Lys Leu Gly Leu Ala
 10 305 310 315 320

act gcg ccc gcg ctg tac gca tgg gaa gag ttc ccg gag atg ggc cag 1008
 15 Thr Ala Pro Ala Leu Tyr Ala Trp Glu Glu Phe Pro Glu Met Gly Gln
 325 330 335

20

atg att ctc cgc aag ttt gag aac gaa ggc gat gtc gaa act gcc agg 1056
 Met Ile Leu Arg Lys Phe Glu Asn Glu Gly Asp Val Glu Thr Ala Arg
 340 345 350

25

aat cta gta aga aag tca gct gga ccg gaa aag acc gtg aaa ttg gcg 1104
 Asn Leu Val Arg Lys Ser Ala Gly Pro Glu Lys Thr Val Lys Leu Ala
 355 360 365

30

gaa aaa cat gcc gca ctc gca atg gag gcc ctg cag gga ttg ccg gag 1152
 Glu Lys His Ala Ala Leu Ala Met Glu Ala Leu Gln Gly Leu Pro Glu
 35 370 375 380

40

tcg gac gct aga gaa gcg ctc gaa ggc ctg acc aag act gtg ctc aac 1200
 Ser Asp Ala Arg Glu Ala Leu Glu Gly Leu Thr Lys Thr Val Leu Asn
 385 390 395 400

45

cga aca aag tag 1212
 Arg Thr Lys
 403

50

<210> 6

<211> 403

<212> PRT

55

<213> Rhodotorula minuta

<400> 6

5

Met Ile Phe Asp Pro Leu Gln Leu Val Gly Asn Glu Leu Ser Ser
 1 5 10 15

10

Leu Arg Ser Asn Val Gln Ala Leu Leu Gly Ser Gly His Pro Ala
 20 25 30

15

Leu Asp Thr Ile Ala Lys Tyr Tyr Phe Gln Ala Glu Gly Lys His
 35 40 45

20

Ile Arg Pro Met Ile Val Leu Leu Met Ser Gln Ala Thr Asn Gly
 50 55 60

25

Leu Ala Pro Gly Phe Glu Glu Arg Ser Lys Leu Glu Leu Ser Gly
 65 70 75

30

Arg Lys Gln Thr Asp Pro Ser Arg Ser Ile Asn Asp Pro Leu Glu
 80 85 90

35

Val Lys Ala Asp Glu Ile Leu Asn Asp Ser Asn Pro Ser Ser Phe
 95 100 105

40

Ala Ala Ser Ser Ser Ser Pro Leu Asp Ser Met Pro Ser Thr Ser
 110 115 120

45

Asn Val Leu Pro Ser Gln Arg Arg Leu Ala Glu Ile Thr Glu Met
 125 130 135

50

Ile His Val Ala Ser Leu Leu His Asp Asp Val Ile Asp Gly Ser
 140 145 150

55

Ala Met Arg Arg Ala Gln Ala Ser Ala Pro Ala Ala Phe Gly Asn

	155	160	165
5	Lys Ile Ser Val	Leu Gly Gly Asp Phe Leu Leu Ala Arg Ala	Ser
	170	175	180
10	Leu Tyr Leu Ser Arg Leu Gly Ser Asn Glu Val Val Glu Leu Val		
	185	190	195
15	Ala Ser Val Leu Ala Asn Leu Val Glu Gly Glu Val Met Gln Ile		
	200	205	210
20	Lys Gly Asn Ala Pro Glu Ser Asn Ala Ser Gly Ser Lys Glu Val		
	215	220	225
25	Ala Val His Arg Leu Thr Pro Glu Ile Phe Glu His Tyr Met Lys		
	230	235	240
30	Lys Thr Tyr Leu Lys Thr Ala Ser Leu Ile Ala Lys Ser Thr Arg		
	245	250	255
35	Ala Thr Thr Ile Leu Gly Gly Ala Gly Glu Lys Gln Gly Trp Ile		
	260	265	270
40	Glu Gly Glu Arg Ile Lys Asp Ile Ala Tyr Ser Tyr Gly Arg Asn		
	275	280	285
45	Leu Gly Ile Ala Phe Gln Leu Val Asp Asp Leu Leu Asp Phe Thr		
	290	295	300
50	Ala Thr Asp Ala Gln Phe Gly Lys Pro Ser Gln Gly Ala Asp Leu		
	305	310	315
55	Lys Leu Gly Leu Ala Thr Ala Pro Ala Leu Tyr Ala Trp Glu Glu		
	320	325	330

Phe Pro Glu Met Gly Gln Met Ile Leu Arg Lys Phe Glu Asn Glu
335 340 345

5

Gly Asp Val Glu Thr Ala Arg Asn Leu Val Arg Lys Ser Ala Gly
350 355 360

10

Pro Glu Lys Thr Val Lys Leu Ala Glu Lys His Ala Ala Leu Ala
365 370 375

15

MET Glu Ala Leu Gln Gly Leu Pro Glu Ser Asp Ala Arg Glu Ala
380 385 390

20

Leu Glu Gly Leu Thr Lys Thr Val Leu Asn Arg Thr Lys
395 400 403

25

30

35

40

45

50

55

Claims**1. A DNA of the following (a),(b) or (c):**

- 5 (a) a DNA whose base sequence is as described under SEQ ID NO:1;
 (b) a DNA having a DNA sequence derived from the base sequence shown under SEQ ID NO:1 by deletion, addition, insertion and/or substitution of one or several bases and encoding a protein having decaprenyl diphosphate synthase activity;
 10 (c) a DNA capable of hybridizing with a DNA comprising the base sequence shown under SEQ ID NO:1 under stringent conditions and encoding a protein having decaprenyl diphosphate synthase activity.

2. A DNA of the following (d),(e) or (f):

- 15 (d) a DNA whose base sequence is as described under SEQ ID NO:3;
 (e) a DNA having a DNA sequence derived from the base sequence shown under SEQ ID NO:3 by deletion, addition, insertion and/or substitution of one or several bases and encoding a protein having decaprenyl diphosphate synthase activity;
 20 (f) a DNA capable of hybridizing with a DNA comprising the base sequence shown under SEQ ID NO:3 under stringent conditions and encoding a protein having decaprenyl diphosphate synthase activity.

3. A protein of the following (g) or (h):

- 25 (g) a protein whose amino acid sequence is as described under SEQ ID NO:2;
 (h) a protein having an amino acid sequence derived from the amino acid sequence shown under SEQ ID NO: 2 by deletion, addition, insertion and/or substitution of one or several amino acid residues and having decaprenyl diphosphate synthase activity.

4. A protein of the following (i) or (j):

- 30 (i) a protein whose amino acid sequence is as described under SEQ ID NO:4;
 (j) a protein having an amino acid sequence derived from the amino acid sequence shown under SEQ ID NO: 4 by deletion, addition, insertion and/or substitution of one or several amino acid residues and having decaprenyl diphosphate synthase activity.

5. A DNA encoding the protein according to Claim 3.**6. A DNA encoding the protein according to Claim 4.****7. An expression vector resulting from insertion of the DNA according to Claim 1, 2, 5 or 6 into a vector for expression.****8. The expression vector according to Claim 7, wherein the vector for expression is pUCNT.****9. The expression vector according to Claim 8, which is pNTRm2.****10. The expression vector according to Claim 8, which is pNTRm6.****11. A transformant resulting from transformation of a host microorganism with the DNA according to Claim 1, 2, 5 or 6.****12. A transformant resulting from transformation of a host microorganism with the expression vector according to Claim 7, 8, 9 or 10.****13. The transformant according to Claim 11 or 12, wherein the host microorganism is a strain of *Escherichia coli*.**

14. The transformant according to Claim 13,
wherein the strain of *Escherichia coli* is *Escherichia coli* HB101.
- 5 15. The transformant according to Claim 14,
which is *E. coli* HB101(pNTRm2) (FERM BP-7333).
16. The transformant according to Claim 14,
which is *E. coli* HB101(pNTRm6) (FERM BP-7332).
- 10 17. A process for producing coenzyme Q₁₀,
which comprises cultivating the transformant according to Claim 11, 12, 13, 14, 15 or 16 in a medium and
recovering coenzyme Q₁₀ thus formed and accumulated in the medium.
- 15 18. A DNA of the following (k), (l) or (m):
(k) a DNA whose base sequence is as described under SEQ ID NO:5;
(l) a DNA having a DNA sequence derived from the base sequence shown under SEQ ID NO:5 by deletion,
addition, insertion and/or substitution of one or several bases and
encoding a protein having decaprenyl diphosphate synthase activity;
20 (m) a DNA capable of hybridizing with a DNA comprising the base sequence shown under SEQ ID NO:5 under
stringent conditions and
encoding a protein having decaprenyl diphosphate synthase activity.
- 25 19. A protein of the following (n) or (o):
(n) a protein whose amino acid sequence is as described under SEQ ID NO:6;
(o) a protein having an amino acid sequence derived from the amino acid sequence shown under SEQ ID NO:
6 by deletion, addition, insertion and/or substitution of one or several amino acid residues and having deca-
prenyl diphosphate synthase activity.
- 30 20. A DNA encoding the protein according to Claim 19.
21. An expression vector resulting from insertion of the DNA according to Claim 18 or 20 into a vector for expression.
- 35 22. The expression vector according to Claim 21,
wherein the vector for expression is pUC18.
23. The expression vector according to Claim 22,
which is pUCRm3.
- 40 24. A transformant resulting from transformation of a host microorganism with the DNA according to Claim 18 or 20.
25. A transformant resulting from transformation of a host microorganism with the expression vector according to Claim
21, 22 or 23.
- 45 26. The transformant according to Claim 24 or 25,
wherein the host microorganism is a strain of *Escherichia coli*.
27. The transformant according to Claim 26,
wherein the strain of *Escherichia coli* is *Escherichia coli* DH5 α .
- 50 28. The transformant according to Claim 27,
which is *E. coli* DH5 α (pUCRm3) (FERM BP-7638).
- 55 29. A process for producing coenzyme Q₁₀,
which comprises cultivating the transformant according to Claim 24, 25, 26, 27 or 28 in a medium and re-
covering coenzyme Q₁₀ thus formed and accumulated in the medium.

Fig.1

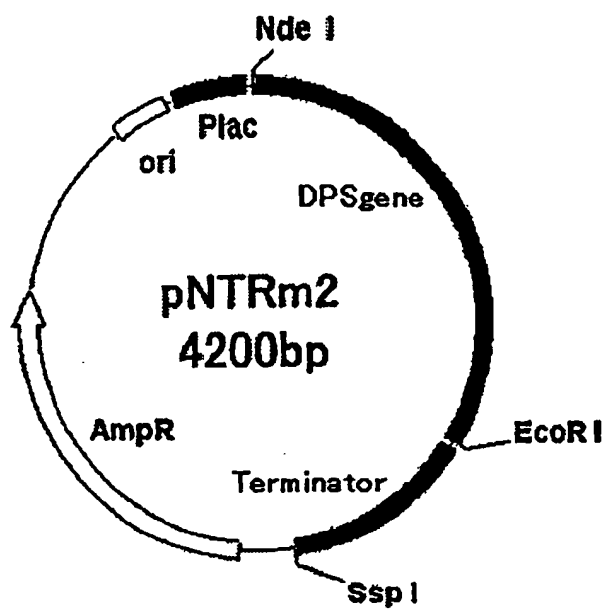


Fig.2

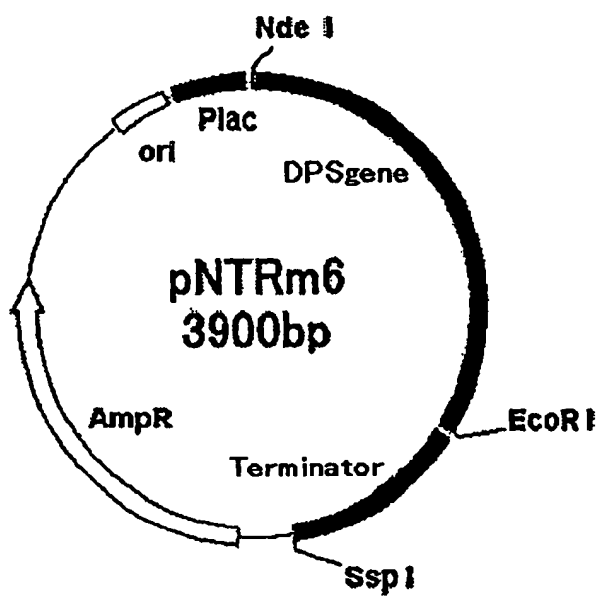


Fig.3

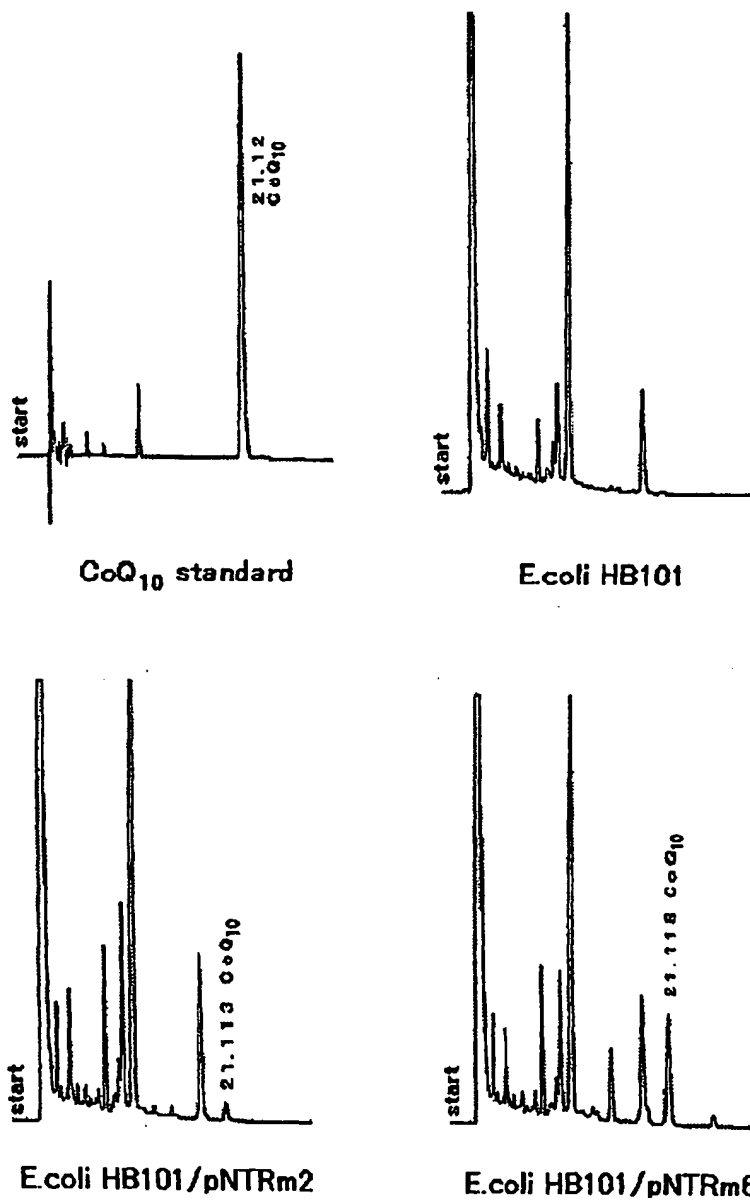


Fig. 4

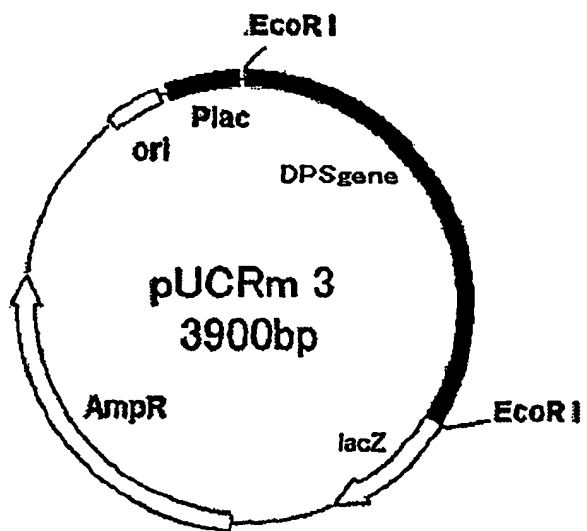
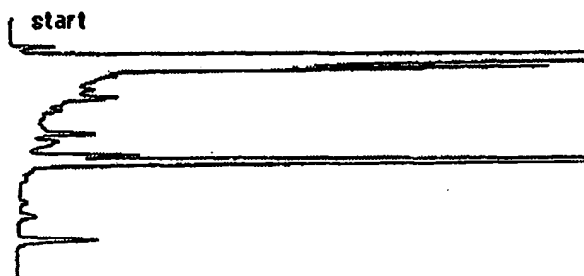


Fig.5

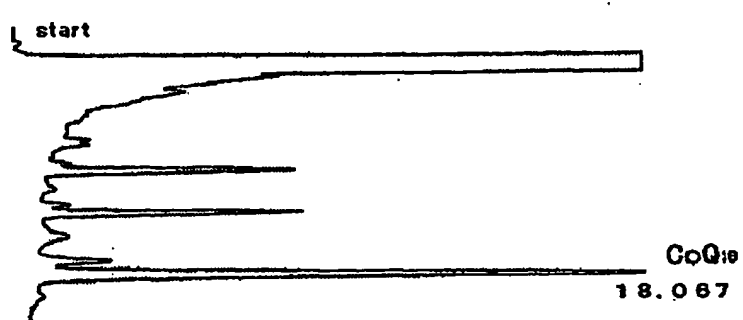
CoQ₁₀ standard



E.coli DH5 α



E.coli DH5 α /pUCRm3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP01/10119

A. CLASSIFICATION OF SUBJECT MATTER		
Int.Cl ⁷ C12N15/54, C12N1/21, C12P7/66, C12N9/12		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
Int.Cl ⁷ C12N15/54, C12N1/21, C12P7/66, C12N9/12		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
JICST FILE (JOIS), WPI (DIALOG), BIOSIS (DIALOG), MEDLINE (STN), PROSITE, EMBL/DBJ/Genbank/PIR/SwissProt/Geneseq		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, 6103488, A (Alpha Foods Co., Ltd.), 15 August, 2000 (15.08.00), Column 2, lines 29 to 50; Fig. 3 & JP 11-56372 A	1-29
Y	EP, 812914, A2 (Toyota Jidousha K.K.), 17 December, 1997 (17.12.97), Page 2, lines 49 to 50; page 5, line 39 to page 6, line 50; Fig. 2 & JP 10-57079 A & US 6071733 A	1-29
Y	JP, 11-178590, A (Toyota Jidousha K.K.), 06 July, 1999 (06.07.99), Page 3; Par. No. [0015], column to page 5, Par. No. [0024], column & US 6225097 B1 & US 2001-19838 A1	1-29
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 07 March, 2002 (07.03.02)		Date of mailing of the international search report 19 March, 2002 (19.03.02)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP01/10119

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 10-57072, A (Alpha Foods Co., Ltd.), 03 March, 1998 (03.03.98), Page 3, Par. No. [0007], column to page 5, Par. No. [0008], column (Family: none)	1-29
Y	KOYAMA T. et al., Thermostable Farnesyl Diphosphate Synthase of Bacillus stearothermophilus: Molecular Cloning, Sequence Determination, Overproduction, and Purification, J.Biochem. (1993), Vol.113, No.3, pages 355 to 363; Figs. 8, 9	1-29
A	TADA M. et al., Mechanism of Photoregulated Carotenogenesis in Rhodotorula minuta VI. Photocontrol of Ubiquinone Production, Plant Cell Physiol. (1989), Vol.30, No.8, pages 1193 to 1196	1-29
Y	US, 4220719, A (AIDA Ko), 02 September, 1980 (02.09.80), Column 2, lines 29 to 50; Fig. 3 & JP 54-126792 A	1-29

Form PCT/ISA/210 (continuation of second sheet) (July 1998)